U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

Subject: DYNAMIC EVALUATION OF SEAT RESTRAINT SYSTEMS & OCCUPANT RESTRAINT FOR ROTORCRAFT (NORMAL AND TRANSPORT)

Date: 3/30/92
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AC No: 20-137
Change:

1. PURPOSE. This advisory circular (AC) provides guidance regarding acceptable means, but not the only means, of compliance with Parts 27 and 29 of the Federal Aviation Regulations (FAR) applicable to dynamic testing of seats intended for use in normal and transport category rotorcraft.

2. RELATED FAR SECTIONS. FAR Sections 27.562, 27.785, 29.562, and 29.785 (Amendments 27-25 and 29-29; 54 FR 47310, 11/13/89).

3. READING MATERIAL. AC Nos. 23.562-1, Dynamic Testing of Part 23 Airplane Seat/Restraint Systems and Occupant Protection, 6/22/89, and 25.562-1, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, 3/6/90. In addition SAE Aerospace Standard AS8049, "Performance Standard for Seats in Civil Rotorcraft and Transport Airplanes," issued July 1990, contains pertinent information. In the future, by notice and public procedure, the FAA intends to incorporate most of this AC material into AC Nos. 27-1, Certification of Normal Category Rotorcraft, and 29-2A, Certification of Transport Category Rotorcraft.

4. BACKGROUND.

a. Improved occupant restraint in civil rotorcraft is addressed in Amendments 27-25 and 29-29 to the airworthiness standards, which add two dynamic crash impact design conditions for seat and occupant restraint systems and which also increase the static design load factors for the occupant seating devices. These amendments also prescribe a shoulder harness for each occupant and adopt human impact injury criteria as a measure for occupant protection for the dynamic crash impact conditions. In addition, these amendments significantly improve occupant protection for normal and transport category rotorcraft in a survivable emergency landing. This advisory material addresses the dynamic test conditions and the related pass-fail injury criteria but not the static design standards. This material pertains to single as well as multiple seats and tandem arrangements of the seats in rotorcraft.

b. Dynamic test methods. This AC focuses on the use of dynamic test methods for evaluating the performance of rotorcraft seats, occupant and seat restraints, and certain related interior systems for demonstrating structural strength and the ability of those systems to protect an occupant from possible injuries in an emergency landing environment represented by the standard. These test methods differ from static test methods, which are limited to demonstrating only the structural strength of the seat or restraint system under ultimate load for at least 3 seconds. This AC contains sources for appropriate test procedures and provides some insight into the logic of these procedures. It also defines, in part, a test facility and equipment characteristics necessary for conducting these tests.

c. Standardized test methods. Dynamic tests are quite often conducted at a specially equipped facility, one other than that owned by the designer or manufacturer of the test article. To obtain consistent test results, the applicant should specify the critical test procedures in detail in the test plan, and then carefully follow these procedures when conducting the tests. This AC defines certain critical procedures for accomplishing the tests of the seat and restraint systems and assessing the data obtained in the tests. Many of these procedures, also found in AC's 23.562-1 and 25.562-1, are accepted as standards by government and commercial test facilities and have been modified in this AC only as necessary for the specific testing of rotorcraft systems.

d. Relationship of dynamic tests to design standards. This AC describes test procedures useful in assessing the performance of a seat, restraint, and interior system. However, it is impractical to conduct sufficient tests for assessing the performance of the system throughout its entire range of possible uses in unique interior arrangements. The designer should not consider the tests described in this AC as sufficient to represent the entire range of performance expected of a system. The seat, restraint, and related interior system should be designed for the range of occupants and environments for which it is expected to perform, not just for the dynamic test conditions described in this AC. For example, the design should consider:

(1) Occupant size. The dynamic tests are conducted with a specific, acceptable, standard anthropomorphic test dummy (ATD) representing a 50th percentile male occupant. Energy absorbing systems, restraint system loads and anchorage locations, seat adjustments, seat pitch (for multiple seat rows), head strike envelopes, etc., are typical factors directly influenced by occupant size.

(2) Seat position and location. The tests should be sufficient to represent the range of performance expected of a seat and restraint system. A seat, especially an adjustable flight crew seat, should be qualified for those positions approved for take-off and landing. As with static test procedures the seat is also tested to the most critical condition for the dynamic tests. For an adjustable flight crew seat, as an example, the full-up position and longitudinal impact case are expected to be the critical condition. But these dynamic tests and occupant injury assessment provide a systems approach to qualification. It is therefore necessary to test adjustable seats at the "design" position for the ATD. Two tests would be required to demonstrate compliance with the strength standards and with the occupant injury criteria. Alternatively adjusting the flight crew seat to its highest position with the interior features, such as an instrument panel shield, raised to maintain the proper perspective or relation to the ATD, is considered an acceptable test procedure for demonstrating compliance with the structural and occupant injury

requirements for the seat and its location in a particular cockpit arrangement.

(3) Test conditions. Only two impact tests are described in the dynamic test procedures discussed in this AC. The test procedures address typical seat and restraint system installations. Other types of seat and restraint system installations may differ from the typical installation to the extent that additional tests may be required to demonstrate compliance. For example, while only one lateral load direction is specified in the tests, the system should perform properly when similarly loaded from either side.

(4) Floor deformation. While provision for evaluating the effect of certain sidewall or floor deformation is included in the tests, the seat and its attachments or restraint system should also perform properly if no floor deformation is present.

(5) Head impact. Should such contact occur, head impact with a seat back or the interior of the rotorcraft is evaluated by using a Head Injury Criterion (HIC), which can be measured directly in the tests discussed in this AC or in supplementary tests of the interior. The design of the interior should protect the head from serious injury throughout the head strike envelope, not just along the head strike paths demonstrated in the test conditions discussed in this AC.

(6) Emergency egress. Standards for emergency evacuation of the rotorcraft are contained in FAR Parts 27 and 29. The transport rotorcraft standards are more explicit than the normal category standards. The objective is to allow each occupant to leave the seat and rapidly evacuate the rotorcraft using an exit on either side of the rotorcraft.

(i) Transport category rotorcraft. Allowable permanent or residual deformation of the seat is specified in this AC. (Refer to § 29.785(j).) Safety belt and harness (i.e., torso restraints) are considered in evaluating compliance (§ 29.785(c)).

(ii) Normal category rotorcraft. Although allowable residual deformation is not specified herein, rapid egress shall be evaluated for the rotorcraft interior arrangement. Refer to §§ 27.785(c) and 27.785(j). The deformation for transport rotorcraft seats in this AC is relevant information.

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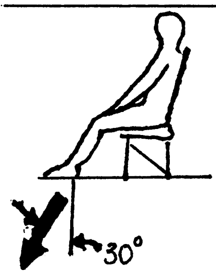
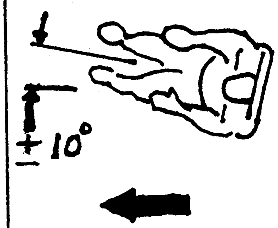
CHAPTER 1. DYNAMIC TEST METHODS AND FACILITIES

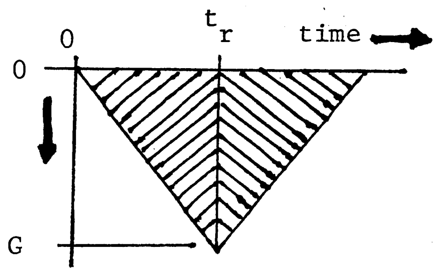
1. General. Two dynamic test conditions are conducted to assess the performance of the seat, restraint, and related interior system. The seat, the restraint, and the nearby interior are all considered to act together as a system to protect the occupant during emergency landing. The specific test conditions are shown in Figure 1. Explanations of the test conditions are as follows:

a. Test 1. The test determines the protection provided when the impact environment is such that the resulting predominant impact load component (vertical) is directed along the spinal column of the occupant in combination with a horizontal (longitudinal) component. Protection against spinal injury is important; energy absorbing (load limiting) or attenuation capability in the seat system is used to reduce the vertical loads as prescribed in the pass-fail criteria.

b. Test 2. The test determines the protection provided in an impact where the predominant impact load component is in the longitudinal direction in combination with a lateral component. Evaluation of head injury protection is important in this test if the head could strike some interior portion of the rotorcraft or a forward seat. Chest or spinal column injury, which might result from the upper torso restraint (shoulder belt), is also evaluated in this test.

c. Tests 1 and 2. These test conditions are also significant for the structural strength of the system. Both tests should be used to assess submarining (where the seat belt slips above the ATD pelvis) and roll-out of the upper torso restraint system particularly with single, diagonal torso restraint belts. Since external crash forces frequently cause significant structural deformation, simulated floor deformation is specified for the tests to prove the seat design can accommodate the relative deformation between the seat and the floor or sidewall and still function without imposing excessive loads on the seat, the attachment fittings, or floor tracks.

Illustration shows a forward facing seat ATD inertial load shown by arrow: 	Test 1	Test 2
		
Min. V_1, fps	30	42
Max. t_r, sec.	.031	.071
Min. G	30	18.4
Deform floor:		
degrees roll	10	10
degrees pitch	10	10



t_r = rise time
v_1 = impact velocity

Figure 1. Seat Restraint System Dynamic Tests
Transport Category Airplanes

2. Test facilities. A test proposal is prepared for FAA approval and should reflect the capability of the facility. It should be noted that a number of test facilities can be used to accomplish dynamic testing. Test facilities can be grouped into categories based on the method they use to generate the impact pulse (i.e., accelerators, decelerators, or impact with rebound) and whether the facility is a horizontal (sled) design or a vertical (drop tower) arrangement. The test facility is not an "FAA certified" or approved facility. As in all FAA tests, a test proposal, which may refer to certain specific or generic test equipment, must be approved by the FAA. The test may be conducted anywhere, within certain availability or mutually convenient constraints, as long as the test is conducted in accordance with the approved test plan and properly witnessed.

a. Facility Characteristics or Features. Each of the facilities has characteristics which may have advantages or disadvantages with regard to the dynamic tests discussed in this AC. One concern is the rapid sequence of acceleration and deceleration that must take place in the tests. In a landing impact, the acceleration phase (flight) is gradual and usually well separated in time from the deceleration (crash impact) phase. In a test, the deceleration usually closely follows the acceleration. When assessing the use of a facility for the specific test procedures outlined in the recommendations, it is necessary to assess the possible consequences of this rapid sequence of acceleration and deceleration on the test articles and ATD. The standard accommodates the different facilities that are or may be available for the applicant's use. That is, the standards dictate the peak acceleration with a tolerance as stated in this AC. The "decay" in deceleration with respect to time is not dictated, thereby allowing for the different test facility equipment characteristics.

(1) Deceleration sled facilities. In an aircraft crash, the impact takes place as a deceleration, so loads are applied more naturally in test facilities that create the test impact pulse as a deceleration. Since it is simpler to design test facilities to extract energy in a controlled manner than to impart energy in a controlled manner, several different deceleration sled facilities can be found. The deceleration sled facility at the FAA's Civil Aeromedical Institute (CAMI) was referred to in developing the test procedures discussed in this and similar AC's related to airplanes.

(i) The acceleration phase. Sufficient velocity for the test impact pulse acquired in this phase can distort the test results if the acceleration is so high that the test articles or ATD are moved from their intended pre-test position. This inability to control the initial or onset conditions of the test would directly affect the test results. This can be avoided by using a lower acceleration for a relatively long duration and by providing a coast phase (in which the acceleration or deceleration is nearly zero) prior to the impact. This allows any dynamic oscillation in the test articles or the ATD that might be caused by the acceleration to decay. To guard against errors in data caused by pre-impact accelerations, data from the electronic test measurements (accelerations, loads) should be reviewed for the time period just before the test impact pulse to make sure all measurements are at the baseline (zero) level. Photometric film taken of the test should also be reviewed to make certain that the ATD's used in the test and the test articles were all in their proper position prior to the test impact pulse.

(ii) Orientation of test article. The horizontal test facility readily accommodates forward-facing seats in both tests discussed in this AC, but problems can exist in positioning the test ATD in Test 1 if the seat is a rear or side facing seat. In these cases, the ATD's tend to fall out of the seat due to the force of gravity and must be restrained in place using break-away tape, cords, or strings. Since each installation will present its own problems, there is no simple, generally applicable, guidance. Attention should be given to positioning the ATD against the seat back and to proper positioning of the ATD's arms and legs. It will probably be necessary to build special supports for a break-away restraint so that the restraint will not interfere with the function of the seat and occupant restraint system during the test. Photos of the test from "side of track cameras" should be reviewed to make sure that the break-away restraint did break (or become slack) in a manner that did not unduly influence the motion of the ATD or the test articles during the test.

(2) Acceleration sled facilities. Acceleration sled facilities, usually based on the Hydraulically Controlled Gas Energized (HYGE) accelerator device, provide the impact test pulse as a controlled acceleration at the beginning of the test. The test item and the ATD are installed facing in the opposite direction from the velocity vector, opposite from the direction used on a deceleration facility, to account for the change in direction of the impact. There should be no problem with the ATD or the test items being out of position due to pre-impact sled acceleration, since there is no sled movement prior to the impact test pulse. Because of this characteristic the applicant may prefer this type of a facility.

(i) Test pulse. After the impact test pulse, when the sled is moving at the maximum test velocity, stop the sled safely. Most of the facilities of this design have limited track length available for deceleration, so that the deceleration levels can be relatively high and deceleration may begin immediately after the impact test pulse. Since the maximum response of the system usually follows (in time) the impact test pulse, any sled deceleration which takes place during that response will affect the response and change the test results. The magnitude of change depends on the system being tested, so that no general "correction factor" can be specified. The effect can be minimized if the sled is allowed to coast, without significant deceleration, until the response is complete.

(ii) Test results. If the seat or restraint system experiences a structural failure during the test pulse, the postimpact deceleration can increase the damage and perhaps result in failures of unrelated components. This will complicate the determination of the initial failure mode and make product improvement more difficult. One other consideration is that the photometric film coverage of the response to impact test pulse must be accomplished when the sled is moving at near maximum velocity. Onboard cameras or a series of track side cameras are usually used to provide film coverage of the test. Since onboard cameras frequently use a wide-angle lens placed close to the test items, it is necessary to account for the effects of distortion and parallax when analyzing the film. The acceleration sled facility faces the same problems in accommodating rearward-facing or side-facing seats in Test 1 as the deceleration sled facility, and the corrective action is the same for both facilities.

(3) Impact-with-rebound sled facilities. One other type of horizontal test facility used is the "impact-with-rebound" sled facility. On this facility, the impact takes place as the moving sled contacts a braking system, which stores the energy of the impact, and then returns the stored energy back to the sled, causing it to rebound in the opposite direction. This facility has an advantage over acceleration or deceleration facilities in that only one-half of the required velocity for the impact would need to be generated by the facility (assuming 100 percent efficiency). Thus the track length can be shortened, and the method of generating velocity is simplified. The disadvantages of this facility combine the problems mentioned for both acceleration facilities and deceleration facilities. Since one of the reasons for this type of facility is to allow short track length to be used, it may be difficult to obtain sufficiently low acceleration just before or after the impact pulse to resolve data error problems caused by significant pre-impact and post-impact accelerations.

(4) Drop towers. Vertical test facilities can include both drop towers (decelerators) and vertical accelerators. Vertical accelerators, which can produce a longer duration/displacement impact pulse, may not be available. However, drop towers are one of the easiest facilities to build and operate and are frequently used.

(i) Acceleration phase. In these facilities, the pull of earth's gravity is used to accelerate the sled or guided test fixture and test article to specified impact velocity to avoid the use of a complex mechanical accelerating system. Reproducing the required impact pulse may require extensive development tests for the facility. Unfortunately, these facilities are more difficult to use for conducting Test 2, particularly for typical forward-facing seats.

(ii) Test article. In preparing for (longitudinal) Test 2, the seat should be installed at an angle according to the standards such that the ATD's tend to fall from the seat due to gravity. The restraint system being tested cannot hold the ATD against the seat unless tightened excessively and will not usually locate the head, arms, or legs in their proper position relative to the seat. Design and fabrication of an auxiliary "break-away" ATD positioning restraint system just for this test are usually a complex task. The auxiliary restraint should not only position the ATD against the seat (including maintaining proper seat cushion deflection) during the pre-release condition of 1 g, it should also maintain the ATD in that proper position during the free fall to impact velocity when the system is exposed to zero g, and then it should release the ATD in a manner that does not interfere with the ATD response to impact. The usual sequence of 1 g/0 g impact, without the possibility of a useful "coast" phase, as done in horizontal facilities, causes shifts in initial conditions for the test impact pulse that can affect the response to the impact. The significance of this undesired movement will depend on the dynamic characteristics of the system under test, and these characteristics are seldom known with sufficient accuracy to achieve the response initially.

(iii) Other facets. In addition, the earth's gravity will oppose the final rebound of the ATD into the seat back, so that an adequate test of seat back strength and support for the ATD cannot be obtained. The problems in Test 1, or with rear-facing seats in Test 2, are not as difficult because the seat will support the ATD prior to the free fall. However, the zero g condition free fall that exists prior to impact will allow the ATD to "float" in the seat restraint system, perhaps changing position and certainly changing the initial impact conditions if movement occurs. Again, the development of a satisfactory auxiliary break-away restraint system to assure correct pre-impact condition is difficult.

b. Test fixtures. A test fixture is usually required to position the test article on the sled or drop carriage of the test facility and to represent the aircraft's structure floor, sidewall, bulkhead, etc. It holds the attachment fittings or floor tracks for the seat, provides the floor and sidewall deformation needed for the test, and provides anchorage points, if necessary, for the torso restraint system. It provides a floor or footrest for the ATD, and it positions the pertinent interior items, such as instrument panels, sidewalls, bulkheads, a second row of seats, if required, for successful performance of the tests, and otherwise simulates the rotorcraft for the test. The test fixture is usually fabricated of heavy structural steel and does not necessarily simulate lightweight aircraft design or construction. The details of the fixture will depend upon the requirements of the test articles, but provisions for the specified floor and sidewall deformation are needed.

(1) Purpose of floor or sidewall deformation. The purpose of using pitch and roll deformation for the tests is to demonstrate that the seat will remain attached to the airframe and perform properly for the tests, although the structure and seat may be more severely deformed by the forces associated

with a particular crash. Typical design deficiencies addressed by the test conditions include, but are not limited to, the following:

(i) Concentrated loads may be imposed on floor fittings (studs) or tracks by seat leg attachment fittings which fit tightly or are clamped to a track or fitting, and which do not have some form of relief (especially lateral roll relief) incorporated in the design. These joint fittings can concentrate the forces on one lip of the floor and sidewall track or stud and may break the joint (track or the fitting).

(ii) Similarly, loads can be concentrated on one edge of a floor track or stud fitting having an "I," "bulb head" or "mushroom" cross section and may prematurely break the flange or the fitting.

(iii) Detents, pins, or collars which lock the seat leg fitting to the floor track can become disengaged, or the mechanism which is used to disengage the detents, pins, or "dogs" can be actuated and release the seat as the seat or airframe deforms.

(iv) Seat assemblies that provide an energy absorbing system between a seat "bucket or pan" and a seat frame attached to the floor may not perform properly after deformation. Deformation of the seat frame may cause the energy absorbers to receive unanticipated loads or cause guides between the seat bucket and seat frame to require excessive force or to lock inadvertently in place due to friction.

(v) Occupant or torso restraint system anchorages attached to the airframe structure may be significantly displaced relative to the seat if the seat deforms, and that displacement may inhibit proper performance of the torso restraint system. This is especially critical for the necessary vertical stroking or displacement.

(2) Floor deformation. Ten degrees (10°) pitch and roll shall be used, where appropriate for the standard. The roll displacement is intended to evaluate the track or stud and leg fitting joint (axis) tolerance to angular misalignment and not necessarily axis translational displacement.

(i) For the typical aircraft seat. For a multiple or single person seat, with four seat legs mounted in the airframe on two parallel tracks, the floor deformation test fixture may consist of two parallel beams, a "pitch beam" which pivots about a lateral (y) axis, and a "roll beam" which pivots about a longitudinal (x) axis. The beams can be made of any fairly rigid structural form, box, I-beam, channel, or other appropriate cross section. The pitch beam should be capable of rotating in the x-z plane up to +/- 10° relative to the longitudinal (x) axis. The roll beam should be capable of a +/- 10° roll about the axis of the seat attachment/fitting joint (centerline of floor track or fittings). (See Figure 2 for a schematic of an installation.) A means should be provided to fasten the beams in the deformed positions.

(ii) Seat and floor interface. The beams should have provision for installing floor tracks or other attachment fittings on their upper surface in a manner that does not alter the above-floor strength of the track or fitting. The track or other attachment fittings should be representative (in above-floor configuration shape and strength) of those used in the rotorcraft. Structural elements below the surface of the floor that are not considered part of the floor track or fitting may be omitted in the installation. The seat having four legs should then be installed on the beams so that the rear seat leg attachment point is near the pitch beam axis of rotation, and the seat positioning pins or locks are fastened in the same manner as specified in the test proposal and as would be used in the rotorcraft, including the adjustment of "anti-rattle" mechanisms, if employed.

(iii) Test set-up. The remainder of the test preparations would then be completed (ATD installation and positioning, instrumentation installation, adjustment and calibration, camera checks, etc.). The "floor deformation" would be induced as the final action before the test is accomplished. The roll beam should first be rotated 10° and locked in place, and then the pitch beam should be rotated 10° and locked in place. The direction of rotation would be selected to produce the most critical loading condition on the seat and floor track or fitting. If the seat is fairly flexible, it may be possible to rotate the beams by manual effort, perhaps using removable pry bars to gain mechanical advantage. However, rotation of the beams used for testing a stiff seat frame is likely to require greater effort than can be accomplished manually, and the use of removable hydraulic jacks or other devices may be necessary. If this condition is expected, provision should be made for appropriate loading points when designing the fixture. This condition is most likely to be encountered when rotating the pitch beam. The test facility personnel should adhere to appropriate safety provisions during the deformation process. The test fixture may be designed to adjust to fit a wide range of seat designs, including leg spacing, that may be encountered.

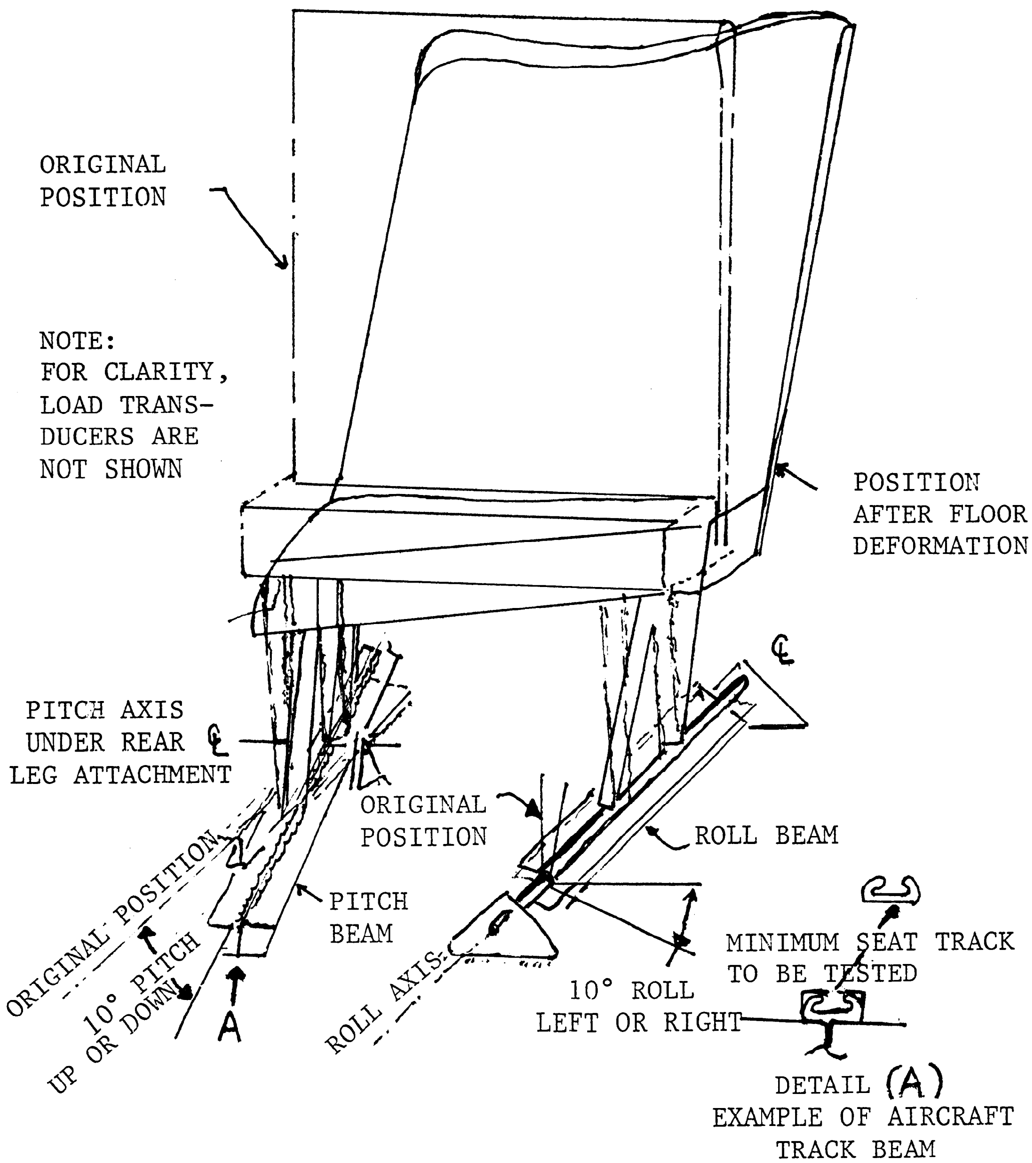


FIGURE 2 - Schematic Floor Deformation Fixture;
Seat Legs Attached at Floor Level

(3) Alternative configurations. The preceding discussion described the fixture and floor deformation procedure which would be used for a typical seat that has four seat legs and four attachments to the fuselage floor. These test procedures may be adapted to seats having other designs. Special test fixtures may be necessary for different configurations. The following methods, while not covering all possible seat designs, provide guidance for the more common configurations of seats:

(i) Rotorcraft seats with three legs may have one central leg in front or back of the seat and one leg on each side of the seat. The central leg should be held in its undeformed position as pitch deformation is applied to one side leg and roll to the other.

(ii) Seats that are "integral" with the structure without floor or sidewall attachment devices and with continuous attachments such as rows of rivets or screw, etc., are excluded from the deformation, misalignment, or preload prior to test impact. Similarly bulkhead-mounted seats, solely mounted to a bulkhead, are excluded from the deformation requirement. The test fixture could represent the seat and structure or a rigid bulkhead or an actual bulkhead panel. If a rigid bulkhead installation is used, the test fixture should transfer loads to the seat restraint system through components equivalent to the seat attachment fittings and surrounding bulkhead panel which exist in the actual installation. Similar guidelines apply to integral seats.

(iii) Seats that are attached to both the floor and a bulkhead would be tested on a fixture which positions the bulkhead surface in a plane through the axis of rotation of the pitch beam. The bulkhead surface should be located perpendicular to the plane of the floor (the rotorcraft floor surface, if one were present) in the undeformed condition or in a manner appropriate to the intended installation. Either a rigid bulkhead simulation or replica or an actual bulkhead panel may be used. If a rigid bulkhead simulation is used, the test fixture should transfer loads to the seat restraint system through components equivalent to the attachment fitting and surrounding bulkhead panel which would exist in the actual installation. The seats would be attached to the bulkhead and the floor in a manner representative of the rotorcraft installation, and the floor, as represented in the test, would then be deformed as described in paragraph 2b(2).

(iv) Seats mounted between fuselage sidewalls or to the sidewall and floor of an airplane should be tested in a manner simulating rotorcraft fuselage cross-section deformation (e.g. from circular or rectangular to flattened circular or rectangular or ellipsoidal shape) during a severe impact. The 10° roll would simulate the change in fuselage shape. Brackets should be fabricated to attach the seat to the sidewall test fixture at the same level above the fixture "floor" that would represent the installation above the rotorcraft floor. The sidewall bracket or rail should be located on the "roll" beam. It is envisaged that the sidewall rolls outward 10° about an axis at the floor and sidewall juncture. Then, as the beams are rotated to produce the critical loading condition, the combined angular and translational deformation would simulate the deformation at the sidewall attachment during a landing impact. (See Figure 3 for a schematic of an installation.)

(v) Seats that are solely cantilevered from one sidewall without connection to another structure would not be subject to floor deformation.

However, sidewall deformation is likely, and should be considered by warping the entire sidewall attachment plane, or the attachment points of the seat, 10° to represent the most likely fuselage sidewall deformation. This is intended to evaluate a critical condition for seat attachment or seat and occupant restraint system performance. Either a rigid sidewall simulation or an actual sidewall panel may be used. If a rigid sidewall simulation is used, the test fixture should transfer loads to the seat through components equivalent to the attachment fitting as well as the surrounding sidewall to replicate the actual installation.

(vi) A seat assembly for multiple occupants may have more than two pairs of legs. If the assembly uses a uniform cross section, deformation of only the outer leg assemblies is sufficient. The inner leg pairs may be maintained in the normal, undeformed position for the dynamic tests.

(4) Multiple row test fixtures. In tests of passenger seats normally installed in rows in a rotorcraft, head impact conditions should be evaluated by tests using at least two rows of seats. This allows direct measurements of the head injury data if secondary head impact occurs and demonstrates the effect of the interaction loads between rows; e.g., due to occupant contact with the front row. (That is, ATD leg contact does not overload the front row.) These conditions are usually critical only on Test 2. The single seat row fixture used for the test should be used to position the front (first) seat row and provide appropriate floor deformation to that row. The test is critical for the first row strength. An additional simple fixture may position the second seat row in the proper location and need not provide floor deformation. The second row should be fully occupied unless it is not as critical a condition for the first seat row. Representative seat cushions and torso restraint systems should be used on both seat rows. The allowable seat pitch (longitudinal spacing) can be determined by analysis of previous test data or limited by type design data and information for the most critical condition for head or leg impact against relatively stiff structure in the first seat row. Operational limitations that specify the allowable seat pitch of the seats in rotorcraft may be considered also. No impact surface such as seats, bulkheads, etc., may be needed for the ATD in the first seat row unless such a surface is within the expected head strike envelope whenever the seats are installed in rotorcraft.

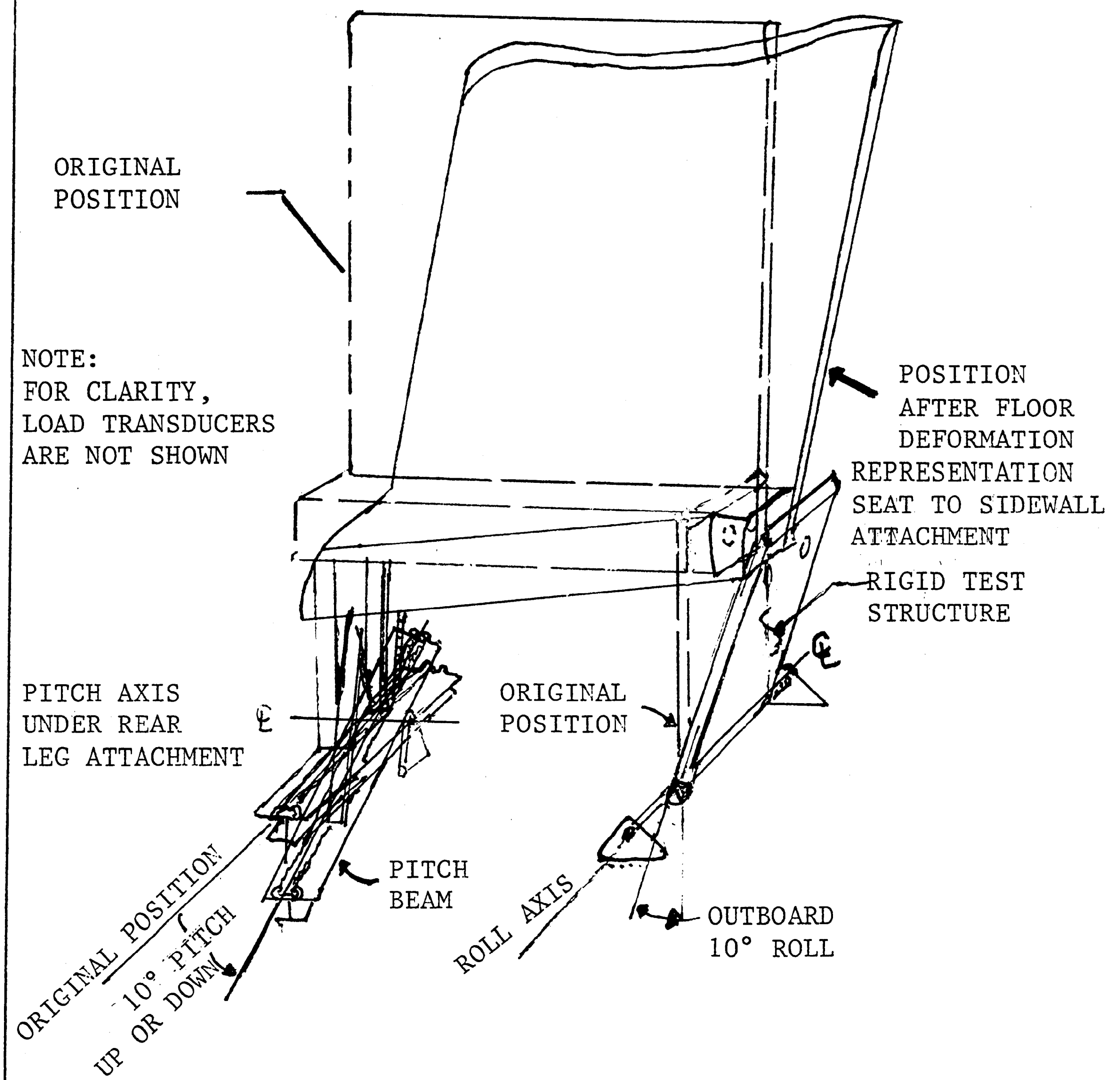


FIGURE 3 - Schematic Test Fixture;
Side Wall Mounted Seat

(5) Other fixture applications. Test fixtures should provide a flat foot rest for an ATD used in tests of passenger and attendant seats. Flightcrew seats associated with special foot rests or foot-operated controls may use simulated foot rests. The surface of the foot rest should be covered with carpet (or other appropriate material) and be at a position representative of the undeformed floor or control. Test fixtures may also be necessary to provide guides or anchors for torso restraint systems or for holding instrument panels or bulkheads if necessary for the proposed tests. If these provisions are necessary, the installation should represent the configuration of the installation and be of adequate structural strength to withstand the expected test loads.

c. Instrumentation. Electronic and photographic instrumentation systems are essential to properly record the information for the tests discussed in this AC. Electronic instrumentation is used to measure accelerations and forces required for verifying the test environment and for measuring most of the pass/fail criteria and the floor (seat) attach loads. Photographic instrumentation is used for recording the overall qualitative results of the tests, for confirming that the lap safety belt remained on the ATD's pelvis (no submarining), and that the upper torso restraint straps remained on the ATD's shoulder, and for recording the relative deformation of the seats as it may influence rapid evacuation of the rotorcraft by the occupants. Chapter 2, Paragraph 10, of this AC contains allowable seat deformation information related to an aisle, passage-way, access to exits, and so forth. Information and descriptions about electronic instrumentation and photographic instrumentation for seat dynamic tests are also found in paragraphs 4b(6)(i) and (ii) of AC 25.562-1 except femur (thigh) loads are not a part of the pass-fail criteria in §§ 27.562 and 29.562, and measurement of the load is not required.

(1) Electronic instrumentation. Electronic instrumentation should be accomplished in accordance with the Society of Automotive Engineers Recommended Practice SAE J211, Instrumentation for Impact Tests. In this practice, a data channel is considered to include all of the instrumentation components from the transducer through the final data measurement, including connecting cables and any analytical procedures which could alter the magnitude or frequency content of the data. Each dynamic data channel is assigned a nominal channel "class" equivalent to the high frequency limit for that channel, based on a constant output/input ratio vs. frequency response plot which begins at 0.1 Hz (+1/2 to -1/2 db) and extends to the high frequency limit (+1/2 to -1 db). Frequency response characteristics beyond this high frequency limit are also specified. When digitizing data, the sample rate should be at least five times the -3 db cutoff frequency of the pre-sample analog filters. Since most facilities set all pre-sample analog filters for Channel Class 1,000 and since the -3 db cutoff frequency for Channel Class 1,000 is 1,650 Hz, the minimum digital sampling rate would be about 8,000 samples per second. For the dynamic tests discussed in this AC, the dynamic data channels should comply with the following channel class characteristics:

(i) Sled or drop tower vehicle acceleration should be measured in accordance with the requirements of Channel Class 60, unless the acceleration is also integrated to obtain velocity or displacement, in which case, it should be measured in accordance with Channel Class 180 requirements.

(ii) Belt restraint system loads should be measured in accordance with the requirements of Channel Class 60.

(iii) ATD head accelerations used for calculating the HIC should be measured in accordance with the requirements of Channel Class 1,000.

(iv) ATD femur forces may be measured if desired in accordance with Channel Class 600.

(v) ATD pelvic/lumbar spinal column force should be measured in accordance with the requirements of Channel Class 600.

(vi) The full-scale calibration range for each channel should provide sufficient dynamic range for the data being measured.

(vii) Digital conversion of analog data should provide sample resolution of not less than 1 percent of full scale input.

(2) Photographic instrumentation. Photographic instrumentation is used for documenting the response of the ATD and the test items to the dynamic test environment. Both high speed motion picture and still systems are used.

(i) High speed motion picture cameras which provide data used to calculate displacement or velocity should operate at a nominal speed of 1,000 pictures per second. Photo instrumentation methods should not be used for measurement of acceleration. The locations of the cameras and of targets or targeted measuring points within the field of view should be measured and documented. Targets should be at least 1/100 of the field width covered by the camera and should be of contrasting colors or should contrast with their background. The center of the target should be easily discernible. Rectilinearity of the image should be documented. If the image is not rectilinear, appropriate correction factors should be used in the data analysis process. A description of photographic calibration boards or scales within the camera field of view, the camera lens focal length, and the make and model of each camera and lens should be documented for each test. Appropriate digital or serial timing should be provided on the image media. A description of the timing signal, the offset of timing signal to the image, and the means of correlating the time of the image with the time of electronic data should be provided. A rigorous, verified analytical procedure should be used for data analysis.

(ii) Cameras operating at a nominal rate of 200 pictures per second or greater can be used to document the response of ATD and test items if measurements are not required. For example, actions such as movement of the pelvic restraint system webbing (lap safety belt) off of the ATD pelvis or movement of upper torso restraint webbing off of the ATD's shoulder can be observed by documentation cameras placed to obtain a "best view" of the anticipated event. These cameras should be provided with appropriate timing and a means of correlating the image with the time of electronic data.

(iii) Still image cameras can be used to document the pretest installation and the posttest response of the ATD's and the test items. At least four pictures should be obtained from different positions around the test items in pretest and posttest conditions. Where an upper torso restraint system is installed, posttest pictures should be obtained before moving the ATD. For the posttest pictures, the ATD'S upper torso may be rotated to the approximate upright seated position so that the condition of the restraint system may be better documented, but no other change to the posttest response of the test item or ATD's should be made. The pictures should document that the seat remained attached at all points of attachment to the test fixture. Still pictures can also be used to document posttest yielding of the seat for the purpose of showing that it would not impede the rapid evacuation of the airplane occupants. The ATD's should be removed from the seat in preparation for still pictures used for that purpose. Targets or an appropriate target grid should be included in such pictures, and the views should be selected so that potential interference with the evacuation process can be determined. For tests where the ATD's head impacts a fixture or another seat back, pictures should be taken to document the head contact areas.

d. ATD. The tests discussed in this AC were developed using modified forms of the ATD specified by the United States Code of Federal Regulations, Title 49, Part 572 Anthropomorphic Test Dummies, Subpart B - 50th Percentile Male. These "Part 572B" ATD's were developed for automobile impact testing and have been shown to be reliable test devices capable of providing reproducible results in repeated testing. However, since ATD development is a continuing process, the standards allow use of "equivalent" dummies. See Chapter 1, Paragraph 2d(4) of this AC. Dummy types should not be mixed when the tests discussed in this AC are performed.

(1) Modification for measuring pelvic/lumbar column load. Since ATD's have been developed for use in automobile testing to evaluate injury protection in forward, rearward, and sideward impacts, the ATD's must be modified to measure the spinal load to comply with the §§27.562(c)(7) and 29.562(c(7). This load is influenced by a vertical direction component and by upper torso restraints which may produce a downward force component on the shoulders. To measure the load, a load (force) transducer is inserted into the ATD pelvis just below the lumbar column. This modification is shown in Figure 4. A commercially available "femur" load cell with end plates removed has been adapted to the modified ATD to measure the compression load between the pelvis and the lumbar spine column of the ATD. A "femur" load cell is commonly available to most test facilities and (according to specifications) is insensitive to bending and twisting moments. This feature prevents load transmission through the load cell as it measures the ATD lumbar/pelvis compression forces. To maintain the correct seated height of the ATD, the load cell is fixed in a rigid cup inserted into a hole bored in the top surface of the ATD pelvis, the top flange of which is bolted to the pelvis. If necessary, ballast should be added to the pelvis to maintain the specified weight of the assembly. Alternative approaches to measuring the axial force transmitted to the lumbar spinal column by the pelvis are acceptable if the method--

(i) Accurately measures the axial force but is insensitive to moments and forces other than that being measured;

(ii) Maintains the intended alignment of the spinal column and the pelvis, the correct seated height, and the correct weight distribution of the ATD; and

(iii) Does not alter the other performance characteristics of the ATD.

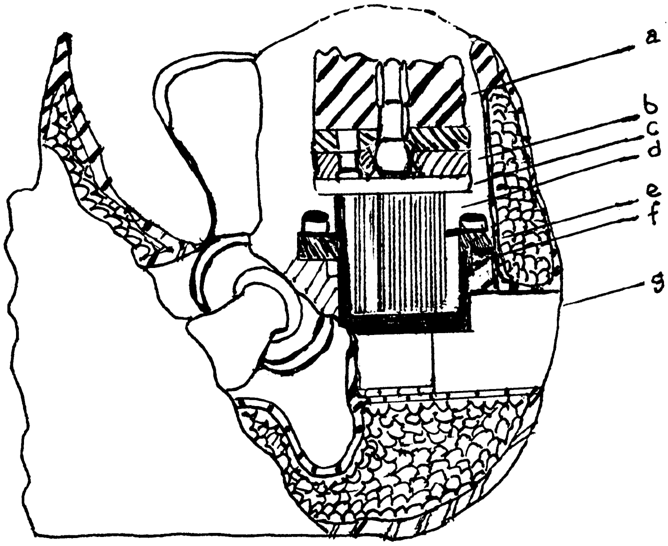


FIGURE 4 - Installation of Pelvic--Lumbar Spine Load Cell in Part 572B Anthropomorphic Dummy.

(2) Figure 4 shows an acceptable installation of a femur load cell (d) at the base of the ATD lumbar spine (a). The load cell is in line with the centerline of the lumbar spine and set below the top surface of the pelvis casting to maintain the seated height of the ATD. A rigid adapter cup (e) is fabricated to hold the load cell, and a hole is bored in the ATD pelvis to accept the cup. Provide clearance between the walls of the adapter cup and the load cell and the wires leading from the cell to avoid possible interference loads. The bottom of the load cell is bolted to the adapter cup. Adapter plates having similar hole patterns in their periphery are fabricated for the lower surface of the lumbar spine (b) and the upper surface of the load cell (c). These plates are fastened to the lumbar spine and load cell with screws through holes matching threaded holes in those components and are then joined together by bolts through the peripheral holes. The flange on the adapter cup has a bolt hole pattern matching that on the pelvis. The cup is fastened to the pelvis using screws to the threaded holes in the pelvis. Spacers (f) may be placed under the flange of the cup to obtain the specified ATD seating height. Additional weight should be placed in the cavity below the adapter cup to compensate for any weight lost because of this modification. The instrument cavity plug (g) is cut to provide clearance for the adapter cup and added weight.

(3) Other ATD modifications. Flailing of the ATD arms often causes the "clavicle" used in the Part 572B ATD to break. To reduce the frequency of this failure, the clavicle may be replaced by a component having the same shape but made of higher strength material. This may increase the ATD weight slightly, but it would be acceptable for the tests discussed in this AC. Another useful modification is the use of "submarining indicators" on the ATD pelvis. These electronic transducers are located on the anterior surface of the ilium of the ATD pelvis without altering its contour and indicate the position of the lap safety belt as it applies loads to the pelvis. Thus they can provide a direct record that the lap safety belt remains on the pelvis during the test and eliminates the need for careful review of high-speed camera images to make that determination.

(4) Equivalent ATD. The continuing development of ATD for dynamic testing of seat restraint/crash-injury-protection systems is guided by goals of improved biofidelity (human-like response to the impact environment) and reproducibility of test results. The following criteria can be used to assess whether or not an ATD is equivalent to the present Part 572B ATD:

(i) Fabrication in accordance with design and production specifications established and published by a regulatory agency responsible for crash injury protection systems;

(ii) Capability of providing data for the measurements discussed in this AC or of being readily altered to provide the data;

(iii) Evaluation by comparison with the Part 572B ATD and shown to generate similar response to the impact environment discussed in this AC; and

(iv) Any deviations from the Part 572B ATD configuration or performance are representative of the occupant of a civil aircraft in the impact environment discussed in this AC.

(5) Temperature and humidity. Since extremes of temperature and humidity can change the performance of ATD, the tests discussed in this AC should be conducted at a temperature from 66°F to 78°F, and at a relative humidity from 10 percent to 70 percent. The ATD should have been maintained under these conditions for at least 4 hours prior to the test.

3. Test Preparation. Preparations for the tests should include selection of the test articles to be used in the tests, determination of the "most critical" conditions for the tests, and installation of the test articles, instrumentation, and ATD on the test fixture. Preparations pertaining to the normal operation of the test facility, such as safety provisions and the actual procedure for accomplishment of the tests, are particular to the test facility. These may be included in a test proposal or plan.

a. Selection of test articles. Many seat designs compose a "family or type" of seats which have the same basic structural design but differ in detail. For example, a basic seat frame configuration can allow for several different seat leg locations to permit installation in different airplanes. If these differences are of such a nature that their effect can be determined by rational analysis, then the analysis can determine the most highly stressed ("most critical") configuration. The most highly stressed configuration would normally be selected for the dynamic tests so that the other configurations could be accepted by analysis and comparison with that configuration. The HIC depends on head impact (secondary impact after rotorcraft ground impact) and is more dependent on seat pitch for multiple row seats and on location for others than on seat structural stress for a given "family" of seats, so that the selection of the most highly stressed seat structure and the most critical seat pitch or location will permit these factors to be evaluated in one dual row test under the conditions of Test 2. Critical pelvic/lumbar spinal column forces are usually found under the vertical impact conditions of Test 1 but are influenced by the upper torso restraint in Test 2. Certain factors should be considered when employing that assumption. For example:

(1) If the test item incorporates some energy absorbing or load limiting design concept necessary to meet the test criteria or other requirement, a less severe loading condition may adversely affect the performance of that design concept as related to the pass-fail criteria. In such a case, it should be shown by rational analysis or additional testing that the design concept would continue to perform as intended even under the lower loads.

(2) If different configurations of the same basic design incorporated load-carrying elements, especially joints or fasteners, which differed in detail design, the performance of each detail design should be demonstrated in a dynamic test. Experience has shown that small details in the design often cause problems in meeting the test performance criteria.

(3) If structural strength is not the critical condition for achieving the performance criteria of the dynamic test, the true critical condition should be evaluated in a dynamic test. For example, if in one of the design configurations the restraint system attachment points are located so that the lap safety belt was more likely to slip above the ATD pelvis during the impact, then that configuration should also be dynamically tested even though the structural loading might be less. In all cases, the test item should be representative of the final production item in all structural elements and should include seat cushions, armrests and armcaps, functioning position adjustment mechanism, and correctly adjusted seat back breakover (if present), food trays or any other service or accoutrement required by the seat manufacturer or customer, and any other items of mass carried or positioned by the seat structure (e.g., weights simulating luggage carried or restrained by luggage restraint bars, fire extinguishers, survival equipment, etc). If these items of mass are placed in a position which could limit the function of

an energy absorbing design concept in the test item, they should be of representative shape and stiffness as well as weight. That is, seat stroking should perform properly when used in rotorcraft interiors.

b. Consideration of test criteria. The test proposal or plan should be planned to achieve "most critical" conditions for the criteria that make up each test.

(1) For multiple occupant seat assemblies, a rational structural analysis should be used to determine the number and seat location for the ATD and the direction for seat yaw in Test 2 to provide the most critical seat structural stress. This will usually result in unequally loaded seat legs. The seat deformation procedure should be selected to increase the load on the highest loaded seat leg and to stress the floor track or fitting in the most severe manner. The seat position in Test 2 depends on the upper torso restraint design. See 3b(3) below.

(2) If multiple row testing is used to gather data for HIC in passenger seats, the seat pitch distance between seat rows should be selected within the allowable range, so that the head would be most likely to contact hard structure in the forward seat row. The effect of the 10° yaw in Test 2 and of any seat back breakover should be considered. Results from previous tests or rational analysis can be used to estimate the head strike path. Upper torso restraints may prevent head strike; however, leg kick loads into the front seat row require use of two rows. This kick load is a seat structural test not an ATD consideration.

(3) If nonsymmetrical upper torso restraints (such as single diagonal shoulder belts) are used in a system, they should be installed on the test fixture in a position representative of that in the aircraft and that would most likely allow the ATD to move out of the restraint. For example, in a forward facing crew seat equipped with a single diagonal shoulder belt, the seat should be yawed in Test 2 in a direction such that the belt passes over the trailing shoulder. This is a part of the pass/fail criteria evaluation.

(4) If a seat has sitting height adjustment, it should be tested in the highest position that could be used by a 50th percentile male occupant in the aircraft installation. See 3d(2) of this AC.

(5) Floor deformation need not be considered in assessing the consequence of any seat deformation as related to the possible impairment of rapid evacuation of the airplane. After the test, the pitch and roll floor beams can be returned to their neutral position and the necessary measurements of the seat deformation made to determine the effect, if any, on rapid evacuation.

(6) In some cases, it may not be possible to measure data for HIC during the test of the seat and torso restraint system. The design of the

surrounding interior, such as the instrument panel, may not be known to the designer of the seat and torso restraint system, or the system may be used in several applications with different interior configurations. In such cases, it will be necessary to document the head strike path and the velocity along the path. This will require careful placement of photo instrumentation cameras and location of targets on the ATD representing the ATD head center of mass so that the necessary data can be obtained. These data can be used by the interior designer to ensure that head impact with the interior will not take place or that if possible head impact occurs, it will remain within the limits of the HIC. In the event the head impacts the specific interior, the interior under evaluation should be subjected to an individual special test to measure the head impact or HIC. The test is done using a rigid 6.5-inch diameter spherical head form weighing 15 pounds (which includes necessary mass to represent the neck and a portion of the torso). The center of the head form is guided along the previously determined head strike path so that the form contacts the interior components at the velocity previously determined during the seat and torso restraint system dynamic test. Accelerometers located at the center of the head form would provide the data necessary for the HIC computation. If the interior component to be impacted by the ATD has significant inertial response to the impact environment, it will be necessary to evaluate those features or systems, such as breakover seatbacks or instrument panels designed to move forward, relative to the seat, in a dynamic test program which includes the full ATD occupant/seat/restraint system. See 3.d(2) of this AC for ATD and panel location for adjustable crew seats.

c. Use of ATD. ATD used in the tests discussed in this AC should be maintained to perform in accordance with the requirements described in their specification. Periodic teardown and inspection of the ATD should be accomplished to identify and correct any worn or damaged components, and appropriate ATD calibration tests (as described in their specification) should be accomplished if major components are replaced. Each ATD should be clothed in form-fitting cotton stretch garments with short sleeves, mid-calf length pants, and shoes (size 11E) weighing about 2.5 pounds. The head and face of the ATD can be coated with chalk dust if it is desired to mark head contact areas on seats or other structure. The friction in limb joints should be set so that the joints barely restrain the weight of the limb when extended horizontally. The ATD should be placed in the seat in a uniform manner for reproducible test results. For the tests discussed in this AC, the following procedures are adequate:

(1) The ATD should be placed in the center of the seat in as nearly a symmetrical position as possible.

(2) The ATD's back should be against the seat back without clearance. This condition can be achieved if the ATD's legs are lifted as it is lowered into the seat. Then, the ATD is pushed back into the seat back as it is lowered the last few inches into the seat pan. Once all lifting devices have

been removed from the ATD, the ATD should be "rocked" slightly to settle it in the seat.

(3) The ATD knees should be separated about 4 inches.

(4) The ATD hands should be placed on the top of the legs, just behind the knees. If tests on crew seats are conducted in a mockup with aircraft controls, the ATD hands should be lightly tied to the controls. If only the seat and occupant restraint system are tested, the ATD hands should be tied together with a slack cord that provides about 24 inches of separation before the cord becomes tight. This will prevent excessive arm flail during the ATD rebound phase.

(5) All seat adjustments and controls should be in the design position intended for the 50th percentile male occupant. If seat and occupant restraint systems being tested are to be used in applications where requirements (placards) dictate particular positions for landing and takeoff, those positions should be used in the tests.

(6) The feet should be in the appropriate position for the type of seat tested (flat on the floor for a passenger seat or on control pedals or on a 45° footrest for flightcrew systems). The feet should be placed so that the centerlines of the lower legs are approximately parallel, unless the need for placing the feet on aircraft controls dictates otherwise.

d. Installation of instrumentation. Professional practice should be followed when installing instrumentation. Care should be taken when installing the transducers to prevent deformation of the transducer body from causing errors in data. Lead-wires should be routed to avoid entanglement with the ATD or test item, and sufficient slack should be provided to allow motion of the ATD or test item without breaking the lead wires or disconnecting the transducer. Calibration procedures should consider the effect of long transducer lead-wires. Head accelerometer (transducer) should be installed in the ATD in accordance with the ATD specification and the instructions of the transducer manufacturer. The load cell between the pelvis and the lumbar spinal column should be installed as shown in Figure 4 of this AC or in a manner that would provide equivalent data.

(1) An upper torso restraint is required by §§ 27.785(b) and 29.785(b). The tension load should be measured in a segment of webbing between the ATD's shoulders and the first contact of the webbing with hard structure (the anchorage point or a webbing guide). Restraint webbing should not be cut to insert a load cell in series with the webbing, since that would change the characteristics of the restraint system. Commercially available load cells can be placed over the webbing without cutting. They should be placed on free webbing and should not contact hard structure, seat upholstery, or the ATD during the test. They should not be used on double-reeved webbing, multiple-layered webbing, locally-stitched webbing, or folded webbing unless it can be

demonstrated that these conditions do not cause errors in the data. These load cells should be calibrated using a length of webbing of the type used in the restraint system. If the placement of the load cell on the webbing causes the restraint system to sag, the weight of the load cell can be supported by light string or tape that will break away during the test.

(2) Loads in restraint systems attaching directly to the test fixture can be measured by three-axis load cells fixed to the test fixture at the appropriate location. These commercially available load cells measure the forces in three orthogonal directions simultaneously, so that the direction as well as the magnitude of the force can be determined. If desired, similar load cells can be used to measure forces at other boundaries between the test fixture and the test item, such as the forces transmitted by the legs of the seat into the floor track. It is possible to use independent, single axis load cells arranged to provide similar data, but care should be taken to use load cells that can withstand significant cross-axis loading or bending without causing errors in the test data, or use careful (often complex) installation to protect the load cells from cross-axis loading or bending. Since load cells are sensitive to the inertial forces of their own internal mass and to the mass of fixtures located between them and the test article, as well as to forces applied by the test article, it may be necessary to compensate the test data for that inaccuracy if the error is significant. Data for such compensation will usually be obtained from an additional dynamic test replicating the load cell installation but will not include the test item.

e. Torso restraint system adjustment. The ATD should be sitting in the normal upright position. Care should be taken not to tighten the restraint system beyond the level reasonably expected in use and not to lock any emergency locking device (inertia reel) prior to the impact. Automatic locking retractors should be allowed to perform the webbing retraction and automatic locking function without assistance. Care should be taken that emergency locking retractors sensitive to acceleration do not lock prior to the impact test because of pre-impact acceleration applied by the test facility that is not present in a landing impact. If "comfort zone" retractors are used, they should be adjusted in accordance with instructions given to the user of the system. If manual adjustment of the restraint system is required, it should be sufficient to remove slack in the webbing, but it should not be adjusted so that it is unduly tight. Since the force required to adjust the length of the webbing can be as high as 11 pounds, a preload of 12-15 pounds is commonly recommended. This load is too small to be accurately measured by transducers selected to measure the high loads encountered in the impact test, so it should be measured manually as the restraint is being adjusted. Special gauges are commercially available to assist in this measurement. The preload should be checked and adjusted, if necessary, just prior to the floor deformation phase of the test.

f. Repetition of tests. It may be necessary to repeat the tests discussed in this AC if accurate data are not collected in critical data channels or if some other error occurs (e.g., cameras fail to operate, impact pulse inadequate, etc.). Preparation for a repeated test should follow the same steps as for the initial test. The seat should be removed from the fixture, and its attachment fittings or floor track examined and replaced, if necessary, to correct any damage. The ATD should be carefully examined and repaired or adjusted, if necessary. It is usually preferable to use a new seat and restraint system for all repeated tests to preclude system failures due to undetected damage. A new seat and restraint system should be used if there is any detectable variation from the intended design configuration.

Chapter 2. DATA ANALYSIS AND COMPLIANCE WITH THE CRITERIA.

1. General. All data obtained in the dynamic tests should be reviewed for errors. Baseline drift, "ringing," and other common electronic instrumentation problems should be detected and corrected before the tests. Loss of data during the test is readily observed in a plot of the data vs. time and is typically indicated by sharp discontinuities in the data, often exceeding the amplitude limits of the data collection system. If these occur early in the test in essential data channels, the data should be rejected and the test repeated. If they occur late in the test, after the maximum data in each channel has been recorded, the validity of the data should be carefully evaluated, but the maximum values of the data may still be acceptable for the tests described in this AC. The HIC does not represent a maximum data value, but represents an integration of data over a varying time base. The head acceleration measurements used for that computation should not be accepted if errors or loss of data are apparent in the data at any time from the beginning of the test until the ATD and all test articles are at rest after the test.

2. Impact pulse shape. Data for evaluating the impact pulse shape are obtained from an accelerometer that measures the acceleration in the direction parallel to the line of inertial response shown in Figure 1 of this AC. The impact pulse intended for the tests discussed in this AC has a symmetrical (isosceles) triangular shape. Since this ideal pulse is considered a minimum test condition, it is possible to evaluate the actual test pulse by comparing it with the ideal triangular pulse. The ideal pulse can be drawn to scale on the data plot of the test sled or carriage acceleration vs. time. The test pulse is acceptable if the plotted data are equal to or greater than the ideal impact pulse. This method can lead to a practical necessity of exceeding the ideal pulse by a significant degree, unless the test facility has precise control in generating the test pulse. To avoid that problem, an alternate graphic technique may be used to evaluate test impact pulse shapes that are not precise isosceles triangles. A graphic technique is contained in Chapter 4, Paragraph 1 of this AC.

3. Head Injury Criterion (HIC). Data for determining the HIC need to be collected during the tests discussed in this AC only if the ATD's head is exposed to secondary impact. The HIC is a method for defining an acceptable limit; i.e., the maximum values of the HIC should not exceed 1,000 for head impact against broad interior surfaces in a crash. The HIC is reported as the maximum value, and the time interval during which the maximum value occurs is also given. Most facilities will make this computation if requested. The HIC is calculated by computer-based data analysis systems because manual attempts to use this method with real data are likely to be tedious. The HIC is calculated according to the following equation:

$$HIC = \left\{ (t_2 - t_1) \left[(1/(t_2 - t_1)) \int_{t_1}^{t_2} a(t)dt \right]^{2.5} \right\}_{MAX}$$

Where: t_1 and t_2 are any two points in the time range during the head impact. The range should not exceed 0.050 seconds, and $a(t)$ is the resultant head acceleration at the center of gravity (expressed in g's) during the head form impact.

a. Data collection. The HIC is commonly based on data obtained from three mutually perpendicular accelerometers installed in the head of the ATD in accordance with the ATD specification. Data from these accelerometers are obtained using a data system conforming to Channel Class 1,000 as described in SAE Recommended Practice J211. For the tests discussed in this AC (both ATD and head form), only the data taken during secondary head impact with the aircraft interior need be considered. Head impact is often indicated in the data by a rapid change in the magnitude of the acceleration. Alternately, a film of the test may show head impact which can be correlated with the acceleration data by using the time base common to both electronic and photographic instrumentation, or simple contact switches on the impacted surface can be used to define the initial contact time.

b. HIC methodology. The following discussion outlines the basic method for computing the HIC. The magnitude of the resultant acceleration vector obtained from the three accelerometers is plotted against time. Then, beginning at the time of initial head contact (t_1), the average value of the resultant acceleration is found for each increasing increment of time ($t_2 - t_1$), by integrating the curve between the range of t_1 and t_2 and then dividing the integral value by the time ($t_2 - t_1$). This calculation should use all data points provided by the minimum 8,000 samples per second digital sampling rate for the integration. However, the maximizing time intervals need be no more precise than 0.001 seconds. The average values are then raised to the 2.5 power and multiplied by the corresponding increment of time ($t_2 - t_1$). This procedure is then repeated, increasing t_1 by 0.001 seconds for each repetition. The maximum value of the set of computations obtained from this procedure is the HIC. The procedure may be simplified by noting that the maximum value will only occur in intervals where the resultant magnitude of acceleration at t_1 is equal to the resultant magnitude of acceleration at t_2 and when the average resultant acceleration in that interval is equal to 5/3 times the acceleration at t_1 or t_2.

c. Limitations. HIC does not consider injuries that can occur from contact with surfaces having small contact areas or sharp edges, especially if those surfaces are relatively rigid. These injuries can occur at low impact velocities, and are often described as "cosmetic" injuries; however, they can involve irreversible nerve damage and permanent disfigurement. While there is no generally accepted test procedure to provide quantitative assessment of these injuries, a judgmental evaluation of soft tissue injuries can be made by assessing tears or cuts in a synthetic skin placed over the ATD's head or a head form during the test. Synthetic skins are discussed in the Society of Automotive Engineers Information Report SAE J202, Synthetic Skins for Automotive Testing.

4. Impact velocity. Impact velocity can be obtained by measurement of a time interval and a corresponding sled displacement occurring just before or after (for acceleration facilities) the test impact, and then dividing the displacement by the time interval. When making such a computation, the possible errors of the time and displacement measurements should be used to calculate a possible velocity measurement error, and the test impact velocity should exceed the velocity shown in Figure 1 by at least the velocity measurement error. If the sled is changing acceleration during the immediate pre-impact interval, or if the facility produces significant rebound of the sled, the effective impact velocity can be determined by integrating the plot of sled acceleration vs. time. If this method is used, the sled acceleration should be measured in accordance with Channel Class 180 requirements.

5. Upper torso restraint system load. The maximum load in the upper torso restraint system webbing can be obtained directly from a plot or listing of webbing load transducer output. If a three-axis load transducer, fixed to the test fixture, is used to obtain these data, the data from each axis should be combined to provide the resultant vector magnitude. If necessary, corrections should be made for the internal mass of the transducer and the fixture weight it supports. This correction will usually be necessary only when the inertial mass or fixture weight is high or when the correction becomes critical to demonstrate that the measurements fall below the specified limits.

6. Compressive load between the pelvis and lumbar column. The maximum compressive load between the pelvis and the lumbar column of the dummy can be obtained directly from a plot or listing of the output of the load transducer at that location. Since most load cells will indicate tension as well as compression, care should be taken that the polarity of the data has been correctly identified.

7. Retention of upper torso restraint straps. Retention of the upper torso restraint webbing straps on the ATD's shoulders can be verified by observation of photometric or documentary camera coverage. The webbing should remain on the sloping portion of the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. The webbing straps should not bear on the neck or side of the head and should not slip to the upper rounded portion of the upper arm during that time period.

8. Retention of lap safety belt. Retention of the lap safety belt on the occupant's (ATD) pelvis can be verified by observation of photometric or documentary camera coverage. The lap safety belt should remain on the ATD's pelvis, bearing on or below each prominence representing the anterior superior iliac spines, until the ATD rebounds after the test impact and the lap safety belt becomes slack. If the lap safety belt does not become slack throughout the test, the belt should maintain the proper position throughout the test. Movement of the lap safety belt above the prominence is usually indicated by an abrupt displacement of the belt into the ATD's soft abdominal insert which can be seen by careful observation of photo data from a camera located to provide a close view of the belt as it passes over the ATD's pelvis. This movement of the belt is sometimes indicated in measurements of lap safety belt load (if such measurements are made) by a transient decrease or plateau in the belt force, as the belt slips over the prominence, followed by a gradual increase in belt force as the abdominal insert is loaded by the belt. Retention of the lap safety belt can also be verified by "submarining indicators" located on the ATD's pelvis. These transducers are essentially a series of small, uncalibrated load cells placed in or above the rim of the ATD's pelvis without changing its essential geometry. They indicate the position of the lap safety belt by producing an electrical signal when they are under load from the belt.

9. Femur load. Measuring femur loads is not required by the rotorcraft standards. If a seat is installed in an aircraft in a manner that will expose the system to loads from an occupant seated behind the seat system as well as the occupant seated in the seat system, the tests discussed in this AC should be conducted in a manner to demonstrate that the system will perform properly under the combined loading. For example, Test 2 should be conducted with at least two rows of seats in place, as the seats in the first row carry the loads from the occupants in the first row, as well as the leg kick loads from the second row (also noted in 3b(1) of this AC).

10. Seat attachment. Documentation that the seat and restraint system has remained attached at all points of attachment should be provided by still photographs that show the intact system components in the load path between the attachment points and the occupant.

11. Seat deformation. Occupant seats evaluated in the tests discussed in this AC can deform permanently, either due to the action of discrete (impact) energy absorber systems included in the design or due to residual plastic deformation of their structural components. If this deformation is excessive, it could impede emergency evacuation. Each seat design may differ in this regard and should be evaluated according to its unique deformation characteristics. Permanent seat deformations are measured on the critically loaded seat subsequent to conduct of the tests required in §§ 27.562 and 29.562. The seat deformation is measured subsequent to completion of the dynamic tests and, where applicable, release of the applied pre-test floor deformation.

a. Seats. The following post-test deformations and limitations regarding emergency egress and access to exits may be used for showing compliance with § 29.785(j):

(1) Forward or Rearward Directions. The forward or rearward deformations should not exceed a maximum of 4.0 inches (100 mm). In addition, the clearance between undeformed seat rows, measured as shown in Figure 5 (Dimension A), should be a minimum of 9.0 inches, except where seat rows lead to Type III or IV exits, where it should be a minimum of 11.0 inches. For seats with deformations exceeding 4.0 inches, the undeformed clearances between seats should be increased accordingly. In addition, at seat rows leading to Type III or IV exits, a minimum of 20 inches clearance, measured above the arm rests, must be maintained between adjacent seat rows. This measurement may be made with the seat backs returned, using no more than original seat back breakover forces, to their pretest upright or structurally deformed position. At other seat rows, the most forward surface of the seat back must not deform to a distance greater than one half of the original distance to the forwardmost hard structure on the seat (see Figure 6).

(2) Downward Direction. There is no limitation on downward deformation, provided it can be demonstrated that the feet or legs of occupants seated aft would not be entrapped. Additionally, the seat bottom rotational deformation from the horizontal, measured at the centerline of each seat pan, should not exceed 20° forward (pitch down) or 35° aft (pitch up). This measurement should be made between the fore and aft extremities of the seat pan structure, considering the final position of the seat pan structure. In no case should rotation of the seat pan cause entrapment of the occupant.

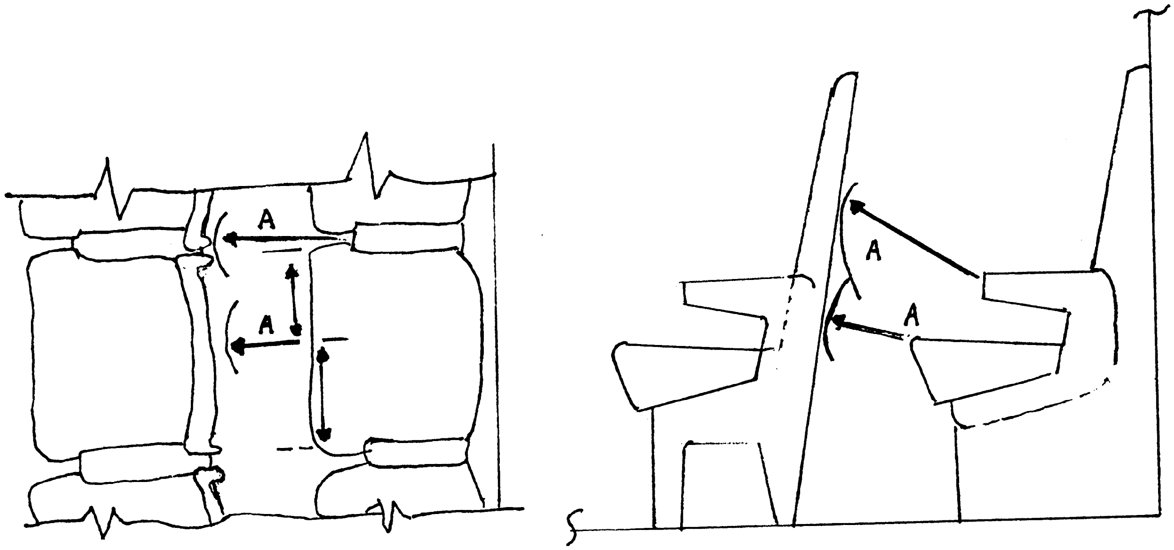
(3) Sideward Direction.

(i) The deformed seat should not encroach more than 1.5 inches (40 mm) into the required space for longitudinal aisle at heights up to 25 inches (635 mm) above the floor. Determine which parts of the seat are at what heights prior to testing.

(ii) The deformed seat should not encroach more than 2.0 inches (50 mm) into the longitudinal aisle space at heights 25 inches (635 mm) or more above the floor.

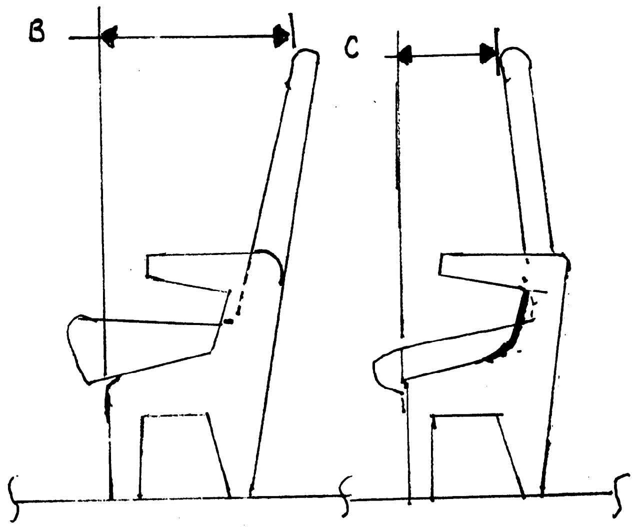
(4) Additional Considerations. In addition, none of the above deformations must permit the seat to:

(i) Affect the operation of any emergency exit or encroach into an emergency exit opening for a distance from the exit not less than the width of the narrowest passenger seat installed except as stated in § 29.813(c)(2).



Measurement to be taken over full width of seat bottom cushion.

FIGURE 5.



Pre-test Condition Posttest Condition
Dimension "C" must be at least 50% of Dimension "B"

FIGURE 6.

(ii) Encroach into any required passageway to large exits, § 29.813(a) and (b).

(iii) Encroach more than 1.5 inches into any cross aisle or evacuation (flight attendant) assist space for certain exits.

b. <u>Stowable Seats</u>. Stowable seats, if used, should stow post-test and remain stowed without projecting into any required passageways. In addition, they should not project more than 1.5 inches into any flight attendant assist space or cross-aisle.

(1) <u>Seats that are Stowed Manually</u>. A post-test stowage force no greater than 10 pounds (22kg) above the original stowage force may be used to stow the seat.

(2) <u>Seats that Stow Automatically</u>. For a seat that may interfere with the opening of any exit, it shall automatically retract to a position that does not interfere with the exit opening as prescribed in §29.807. For determining encroachment into passageways, cross-aisles, and assist spaces, a posttest stowage force no greater than 10 pounds (22kg), applied at a single point, may be used to assist automatic retraction.

Chapter 3. TEST DOCUMENTATION.

1. General. The tests discussed in this AC should be documented in reports describing the test procedures and results. The test proposal, a description of the required tests, approved by the FAA should be referenced in the test report and contain the following:

a. Facility data.

(1) The name and address of the test facility performing the tests.

(2) The name and telephone number of the individual at the test facility responsible for conducting the tests.

(3) A brief description and/or photograph of each test fixture.

(4) The date of the last instrumentation system calibration and the name and telephone number of the person responsible for instrumentation system calibration.

(5) A statement confirming that the data collection was done in accordance with the recommendations in this AC or a detailed description of the actual calibration procedure used and technical analysis showing equivalence to the recommendations of this AC (Chapter 1, Paragraph 2c(1)).

(6) Manufacturer, governing specification, serial number, and test weight of ATD used in the tests, and a description of any modifications or repairs performed on the ATD which could cause them to deviate from the specification.

(7) A description of the photographic-instrumentation system used in the tests (Chapter 1, paragraph 2c(2)).

b. Seat restraint system data.

(1) Manufacturers name and identifying model numbers of the seat restraint system used in the tests, with a brief description of the system, including identification and a functional description of all major components and photographs or drawings as applicable.

(2) For unsymmetric systems, an analysis supporting the selection of most critical conditions used in the tests.

2. Test Proposal or Plan and Description. The description of the test should be documented in enough detail so that the tests could be reproduced by following the guidance given in the report. The procedures outlined in this AC can be referenced in the report but should be supplemented, as necessary, to describe the unique conditions of the individual seat design.

a. Pertinent dimensions and other details of the installation not included in the drawings of the test items should be provided. This can include footrests, restraint system webbing guides and restraint anchorages, "interior surface" simulations, bulkhead or sidewall attachments for seats or restraints, etc.

b. The floor deformation procedure, guided by goals of most critical loading for the test articles, should be documented.

c. Placement and characteristics of electronic and photographic instrumentation chosen for the test, beyond that information provided by the facility, should be documented. This can include special targets, grids or marking used for interpretation of photodocumentation, and transducers and data channel characteristics for lap belt loads, floor reaction forces, or other measurements beyond those discussed in this AC.

d. Any unusual or unique activity or event pertinent to conducting the test should be documented. This could include use of special "breakaway" restraints or support for the ATD's, test items or transducers, operational conditions or activities such as delayed or aborted test procedures, and failures of test fixtures, instrumentation system components or ATD.

3. Test results report. The documentation should include copies of all test results, analysis, and conclusions. As a minimum, the following should be documented:

a. Impact pulse shape (Chapter 2, paragraph 2).

b. HIC results for all ATD exposed to secondary head impact with interior components of the rotorcraft (Chapter 2, paragraph 3), or head strike paths and velocities if secondary head impact is likely for future use in unique interiors (Chapter 1, paragraph 3b).

c. Impact velocity (Chapter 2, paragraph 4).

d. Upper torso restraint system load if applicable (Chapter 2, paragraph 5).

e. Compressive load between the pelvis and the lumbar column (Chapter 2, paragraph 6).

f. Retention of upper torso restraint straps if applicable (Chapter 2, paragraph 7).

g. Retention of lap safety belt (Chapter 2, paragraph 8).

h. Femur thigh loads, optional measurement.

i. Seat attachment (Chapter 2, paragraph 10).

j. Seat deformation (Chapter 2, paragraph 11).

k. Seat attachment reaction time histories (Chapter 4).

4. Dynamic Impact Test - Pass/Fail Criteria: The dynamic impact tests should demonstrate that:

a. The seat structure remains intact that is attached to the tracks or fittings, etc.

b. The occupant retention system is capable of carrying the dynamic loads.

c. The seat permanent deformations are within defined limits and will not significantly impede an occupant from releasing the torso restraints, standing and exiting the seat.

d. If the ATD's head is exposed to impact during the test, a HIC of 1,000 is not exceeded. Data may be obtained for use with other unique installations.

e. Where upper torso restraint straps are used, tension loads in individual straps do not exceed 7.78 kN (1,750 lbs.) If dual straps are used for restraining the upper torso, the total strap tension load does not exceed 8.90 kN (2,000 lbs.).

f. The maximum compressive load measured between the pelvis and the lumbar column of the (ATD) does not exceed 6.67 kN (1,500 lbs.).

g. Each upper torso restraint strap remains on the ATD shoulder during impact.

h. The pelvic restraint remains on the ATD pelvis during impact.

Chapter 4. PROCEDURES FOR EVALUATING IMPACT PULSE SHAPES.

1. Acceptable Evaluation Method. An acceptable method to evaluate the pulse shape should use the following steps:

a. Extend the calibration baseline (zero G) through the plot of test sled or carriage acceleration vs. time.

b. Locate the maximum acceleration (G_p) indicated on the plot.

c. Construct reference lines parallel to the baseline at levels of 0.1 G_p, 0.9 G_p, and 1.0 G_p.

d. Construct an onset line through the intersection points of the 0.1 G_p and 0.9 G_p reference lines with the increasing (onset) portion of the data plot. The data plot should not return to zero G between the two points selected.

e. Locate the intersection points of the onset line with the baseline and with the 1.0 G_p reference line. The interval between these two points, measured along the time axis of the data plot, is considered the rise time (t_r) of the test impact pulse.

f. The rise time of the test impact pulse should not exceed the value of (t_r) given in Figure 1 for each test.

g. The area under the data plot curve within the rise time of the test impact pulse should represent at least one half of the impact velocity given in Figure 1 for each test. If the value of peak acceleration measured in the test exceeds the level given in Figure 1 by no more than 10 percent, the pelvis to lumbar spinal column force and the upper torso restraint force measured in the test may be adjusted by multiplying the measured values by the ratio of the peak acceleration given in Figure 1, divided by the measured peak acceleration, if necessary.

h. The magnitude of G_p should equal or exceed the minimum G given in Figure 1 for each test.

i. The area under the data plot curve from the intersection point of the onset line and the zero G baseline and a time not more than twice the appropriate rise time specified in Figure 1, plus 30 percent of the rise time later, should represent at least the impact during the test.

2. Transport Airplane Impact Pulse and Velocity Plots. The preceding paragraph outlines a graphical procedure for evaluating the impact pulse shape obtained in a test where the pulse shape differs from the shape of an isosceles triangle. While this procedure is based on graphical concepts, a

digital listing of the acceleration and velocity generated during the impact, for every millisecond (0.001 second) of time during the impact, should be used to obtain an accurate evaluation. To illustrate this procedure, consider the transport airplane impact pulse and velocity plots shown below:

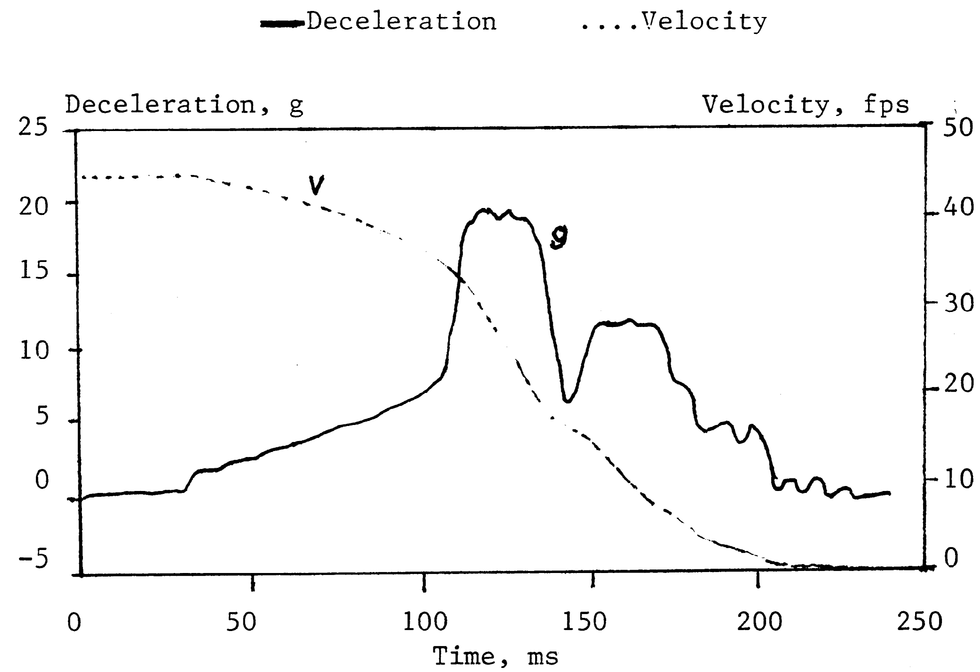


FIGURE 7

a. In Figure 7 the deceleration (negative acceleration) data are shown plotted by the dark line to correspond to the scale at the left. Since this is a deceleration test, the velocity decreases during the test as shown by the dashed line which corresponds to the scale on the right. The purpose of the test was to provide the environment required for Transport Airplane Test 2, similar to Figure 1 Test 2 position of this AC, namely an impact pulse with the shape of an isosceles triangle with a maximum rise time of 90 ms (milliseconds), a peak deceleration of at least 16 g, and an impact velocity of at least 44 fps (feet per second). From the digital listing of the data, it was found that the peak deceleration was 19.43 g and the overall velocity change during the impact was 44.1 fps. However, the shape of the impact pulse does not correspond to the ideal shape of the isosceles triangle. The procedure described in Chapter 2, paragraph 2, will be used to determine if this impact pulse generated an acceptable equivalent to the ideal isosceles triangular shaped pulse and to the conditions which were based on that ideal pulse shape.

b. First, construct the 0 g calibration base line (1 in Figure 8) and locate the peak deceleration (G_p). The data showed that the peak deceleration of 19.43 g occurred at 117 ms.

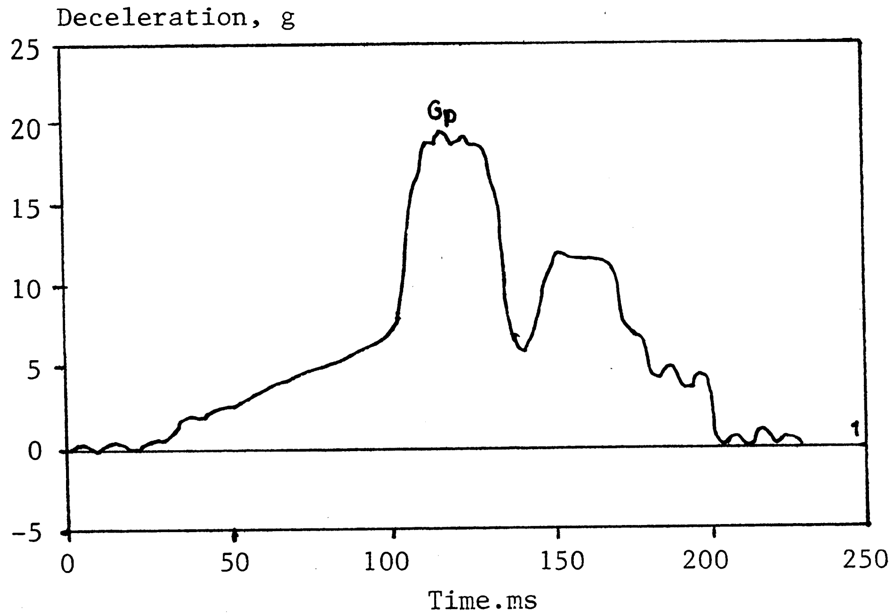


FIGURE 8

c. Next, construct lines parallel to the base line, through G_p and at levels of 0.9 G_p (17.49 g) and 0.1 G_p (1.94 g), shown as lines 2, 3, and 4, respectively, in Figure 9.

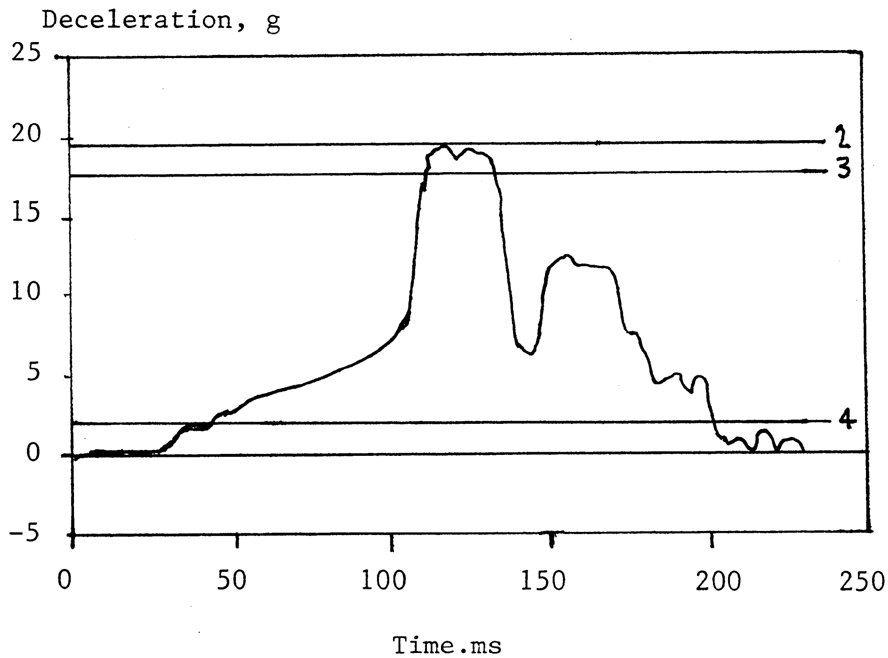


FIGURE 9

d. The next task is to construct an onset line through the intersection of lines 3 and 4 with the deceleration curve. The data showed that the deceleration reached 1.94 g at a time of 44ms, and 17.49 g at 110 ms. These points are identified as "a" and "b" in the figure below, and the onset line is identified as "5". The onset line should be extended until it intersects the G_p line (at point "d") and the base line (at point "c"). These intersection points can be calculated by finding the slope of the onset line:

$$\text{Slope of onset line} = (17.49 - 1.94)/(0.110 - 0.044) = 235.6 \text{ g/s}$$

The time between points "c" and "a" or between points "b" and "d" is then found by dividing the g interval between those points by the slope of the onset line, or 1.94/235.6 = 0.008 s. This time is subtracted from the time of point "a" to obtain the time of point "c". In this manner, we find that the 36 ms and the intersection of the onset line with the line through G_p takes place at (110 + 8) or 118 ms. Note that this latter time will not normally coincide with the time of G_p. The difference between these two times is the rise time, t_r, as referenced in Figure 1 of this AC. Thus t_r is equal to 82 ms, which is the distance between points "c" and "e" in Figure 10.

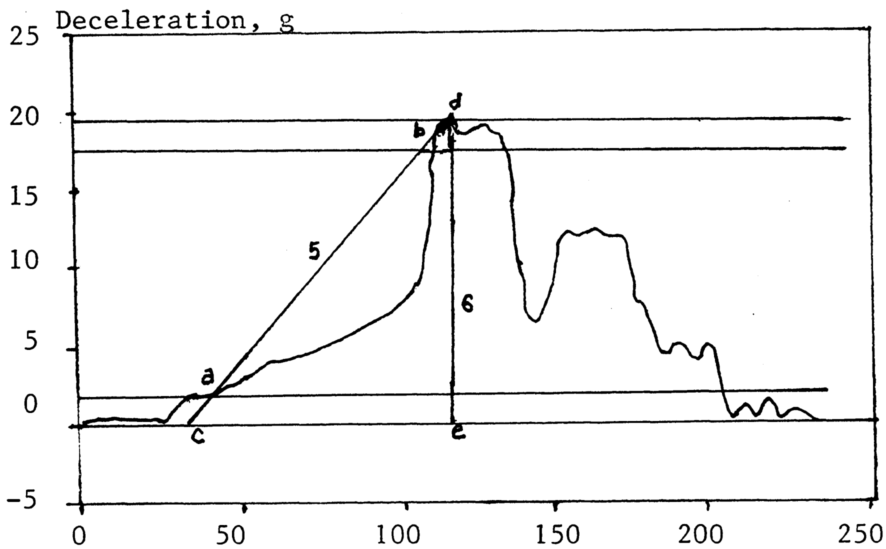


FIGURE 10

e. The area under the data plot from the beginning of the rise time (36 ms) to a time 90 ms later (36 + 90 = 126 ms) represents the velocity change during the period identified as t_r in Figure 1. It can be obtained by integrating the area under the curve between these times (multiply by 32.17 to change "g" to fps^2). Alternatively, from the velocity data listing, it was found that the velocity at 126 ms was 22.52 fps, and the velocity at 36 ms was 43.69 fps, so that the velocity during the rise time was 43.69 - 22.52 = 21.17 fps. In a similar manner, the area under the data plot from the beginning of t_r (point "c") to a time 207 ms (i.e., 2x90 + .03x90) later represents the effective velocity change of the impact pulse. It can be found by integrating the area under the curve from 36 ms to 243 ms or from the velocity data. The data showed that the velocity at 243 ms was only 0.003 fps, so that the effective velocity is 43.69 - 0 = 43.69 fps.

f. The results of applying this procedure to the impact pulse chosen for this example are summarized in Table 1.

Comparison of a Measured Impact Pulse
With Impact Pulse Designated for Test 2
Transport Airplanes

Measure	*Designated	Calculated
Peak g, G_p	At least 16 g	19.43 g
Rise time, t_r	Not more than 0.09 s	0.082 s
Velocity Change During Time Rise	At least 22 fps	21.17 fps
Velocity change	At least 44 fps	43.69 fps

Note: * Reference § 25.562(b)(2).

TABLE 1

g. It can be seen that the velocity change in Table 1 during the rise time of the impact pulse used in this example for a transport airplane is inadequate. Since the response of the seat, restraint, and occupant is sensitive to the rate at which the system is exposed to the impact energy, the example pulse would not be acceptable for the test as described. It is also noted that the total effective impact velocity is also insufficient for the test, even though the overall impact velocity change was greater than the designated minimum. If the impact test facility characteristically produces an impact with a relatively long duration low level "g", either immediately prior to or following the main impact pulse, the rise time to achieve the change in velocity will probably be insufficient.

3. Figures 11 and 12. Figure 11 is an example of a rotorcraft impact pulse for purely vertical deceleration dynamic impact test. This figure and the previous figures illustrate the difference between rotorcraft vertical impact pulse and the transport airplane longitudinal pulse. Figure 12 presents the ATD lumbar (spinal) load associated with this vertical deceleration impact.

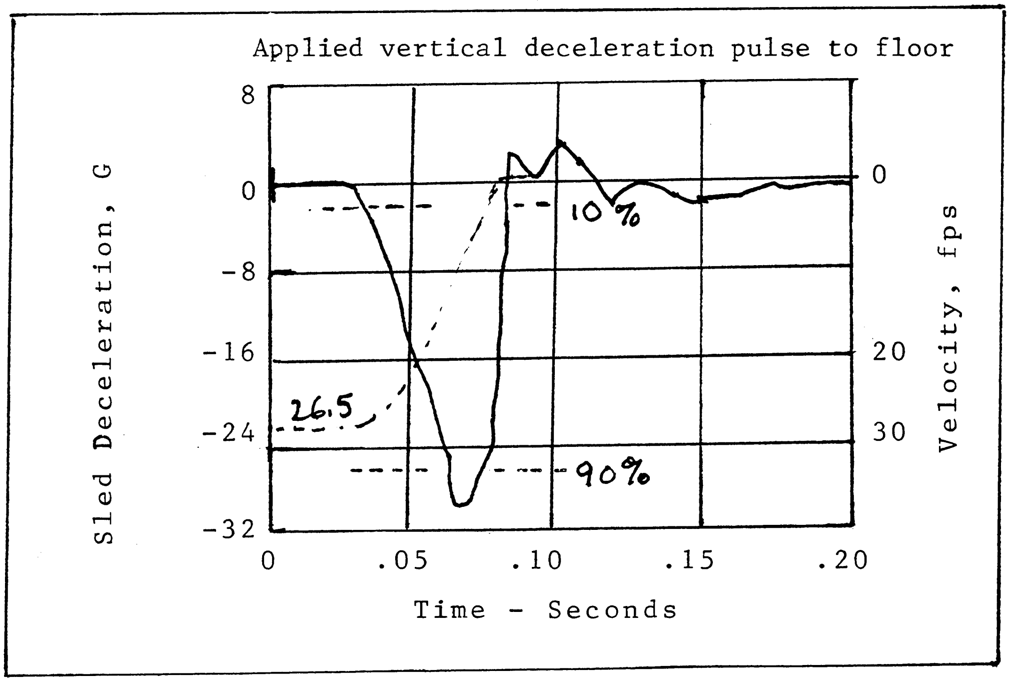


FIGURE 11

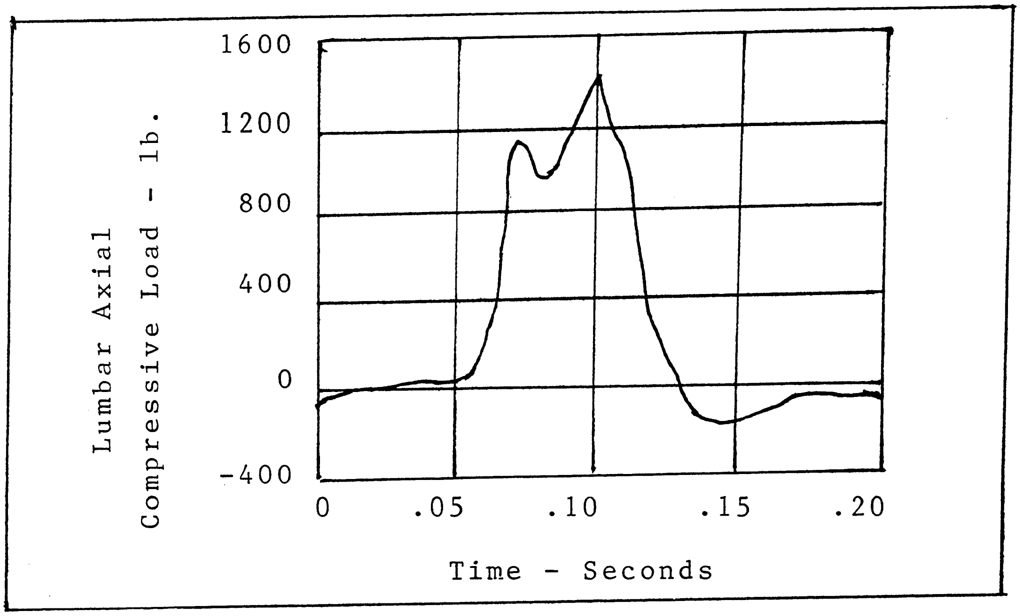


FIGURE 12

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